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COMPUTER MODELING AND NEGOTIATION MANAGEMENT

Dhanesh K. Samarasan*

WP 1957-87 November, 1987

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ABSTRACT: New problems in negotiation call for a new framework of solutions. Negotiation management, one such framework, has at its heart the application of computer models and related technology to a collaborative effort at dispute resolution. In this paradigm, negotiation is treated as a communicative group problem-solving process. Easily accessible techniques are being developed for modeling both the process and substance of negotiation. This paper suggests how these two kinds of models could be combined with other tools and processes in an integrated computer environment for negotiation management.

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1. AN OVERVIEW OF NEGOTIATION MANAGEMENT

Negotiation management [Nyhart & Samarasan, 1987] is an integrated framework for dealing with complex negotiations, and is particularly (although not exclusively) appropriate in contexts where:

i) the points of dispute are technical, and involve a high degree of uncertainty;
ii) practical experimentation with solutions is too expensive or risky;
iii) there is no unquestioned authority to whom the disputing parties all defer; and
iv) prompt resolution and a return to friendly, or at least stable, relations, are desired.

In this paper, 'complex negotiations' are negotiations among several parties about numerous issues. The issues may be independent, but more commonly they are naturally coupled. For want of a better word, 'technical' is used to refer to those issues that spring from specialized scientific or technological controversy. Contemporary examples of technical problems in negotiation would include exploitation of Antarctic resources, U.S.-U.S.S.R. arms reduction, or the economic effect of restrictive tariffs and quotas. When proposals are made in these negotiations, structural problems due to incomplete or inaccurate knowledge cannot be exposed immediately, but neither can the proposals be tested in the real world. If there is no obvious and constructive settlement, the absence of an *unquestioned authority* forces the parties to negotiate under uncertainty. And in most of these cases, *prompt resolution* is rare. The typical alternatives to negotiation – either doing nothing, or calling in the lawyers – are usually costly, lead to extended stalemate, and can be disastrous in the long run.

A far better course in complex negotiations is for the parties to focus first on the removal of as much of the uncertainty as is feasible. They can then proceed to treat the negotiation as a *joint problem-solving process*. Technology, in the form of computers, computer models, and related tools, can be a very powerful aid in this process. When realistic and efficient solution alternatives have been identified through the building and manipulation of models, then intelligent compromise is possible.

Of course, joint problem-solving is incompatible with a traditional, zero-sum approach toward negotiation. Indeed, whenever computer models have so far been employed in negotiation, they have mostly been limited to substantive modeling [for a survey of the field, see Nyhart & Goeltner, 1987], and their most frequent mode of use has been as part of an adversarial strategy [see, for example, Straus & Bazerman, 1985; Weil, 1987]. And even under these restrictive conditions, they have sometimes been ignored altogether when they might have enhanced the process [Clement & Sossen, 1987; Hughes & Van Dusen, in press].

One reason for the disuse of computers and computer models collaboratively in negotiations is the high degree of trust that would be necessary among the parties. In most traditional approaches toward negotiation, there is no need or reason to share information or knowledge with counterparts. Instead, the aim is to force the 'opponent' to yield, because that is the quickest and surest way to gain advantage. Recently, however, the concept of *integrative bargaining*, suggested by Walton & McKersie [1965], has taken on new significance. Integrative bargaining is a cooperative approach in which:

> ... parties attempt to explore options to increase the size of the joint gain without respect to the division of payoffs. The key to this process is openness of communication in order to maximize information about one's own and the other's needs and perspectives, to facilitate discovery of joint gain options [Lewicki, Weiss, & Lewin, 1987].

As shown by Nyhart & Samarasan [1987], the latest works of many specialists in negotiation implicitly or explicitly endorse the concept of integrative bargaining [see, for instance, Fisher & Ury, 1981; Raiffa, 1982; Lax & Sebenius, 1986; Susskind & Cruikshank, 1986; Nyhart & Dauer, 1986]. While the integrative approach is still controversial among practitioners and has profound implications for negotiation strategy, there is preliminary evidence that agreements achieved in this way are of a higher quality, not least in that they withstand better the test of time [Lax & Sebenius, 1986]. It is expected, therefore, that as the practice of integrative bargaining becomes more widespread, the joint use of models should follow.

For the moment, it is clear that computer models and computer technology are a very under-utilized resource in the practice of negotiation. Several analyses of the potential of the computer in negotiation have been made. Most recently, Lukov, Sergeev, and Tyulin [1985] list five trends in modern negotiations that make the computer particularly useful:

i) negotiation problems are increasing in scientific and technological complexity;
ii) larger problems affect and involve more parties, interest groups, and constituencies;
iii) many negotiations result in temporary solutions, and are becoming continuous or periodic institutions;
iv) emerging national and global issues need to be treated comprehensively and efficiently; and
v) change is accelerating and highlighted by the so-called 'information explosion.'

Given this background, one can embark on a more detailed exploration of the application of computers and models in negotiation.

2. A TENTATIVE COMPUTER SYSTEM ARCHITECTURE

In order to address effectively the problems identified in the previous section, a computer system designed for use in negotiation management would provide at least the following functional capabilities:

i) dynamic simulation of the process of negotiation;
ii) dynamic simulation of the substance under negotiation;
iii) channels for communication and experimentation;
iv) analysis of similar precedential disputes and negotiations;
v) risk and decision analysis;
vi) provision of expert knowledge and guidance;
vii) enhancement and optimization of settlements;
viii) modular links to a useful variety of additional tools; and
ix) system-wide model configuration management.

One such system architecture, based on the use of dynamic simulation models of process and substance, is described in this paper. Other writers have developed architectures using other metaphors – an example modeled after a database implementation is presented by Jarke, Jelassi, and Shakun [1985].

Figure 1 is a schematic representation of the various capabilities included in the system. In addition to the tools and processes illustrated in the figure, the architecture also includes storage capacity for knowledge, models, and data. The dynamic process and substantive simulation capabilities (labeled "Simulated Agreement Mechanics" and "Meta-Model Manager," respectively, in Figure 1) are at the core of the architecture, and are described in greater detail in subsequent sections of this paper. The remainder of this section will discuss the choice of an appropriate knowledge representation scheme for a negotiation management system based on process and substantive simulation, and then describe each of the other capabilities in brief and tentative terms.

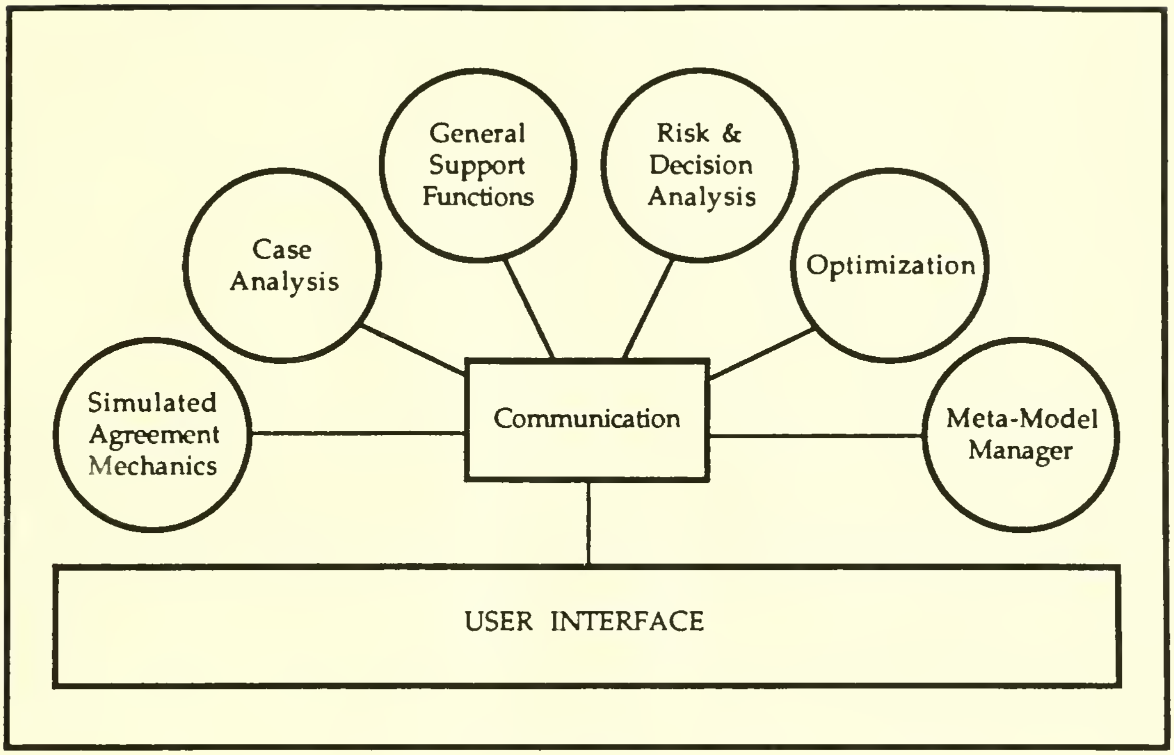

Figure 1: A Tentative System Architecture for Negotiation Management

There are two ways in which the computer is used in negotiation management. It is obviously useful where intensive numeric calculation is required. But even when there is no purely numeric or arithmetical core to structure the calculational use of the computer, symbolic models and symbolic inference techniques are useful. Referring to the list of capabilities enumerated at the beginning of this section, one could classify substantive simulation, optimization, and decision analysis as depending more on arithmetic calculation, and process simulation, precedent analysis, and model management as utilizing mainly symbolic manipulation. Given the variety of capabilities involved, no single knowledge representation formalism is likely to be optimal for all the capabilities that are required.

In any case, three questions have to be answered in the selection of an appropriate knowledge representation scheme for negotiation management. What types of information need to be represented? What units and relations, or data structures, should the representation use? And what inference mechanism(s) are required for the subsequent use of the information by negotiators, by facilitators, and by the system itself?

In negotiation management generally, four categories of knowledge need to be represented: objects, events, skills, and meta-knowledge. *Objects* refer to entities (and classes of entities) found in the negotiation domain, including the parties involved and the various quantities being negotiated. *Events* refer to phenomena in the domain, and exhibit both time-dependencies and causal relationships. For example, the complicated feedback loops in a simulation model of process or substance would consist of chains of events. *Skills*, such as the ability of the system to calculate the expected value of a particular settlement, or to spot key variables in a simulation through sensitivity analysis, might also be represented through heuristic or algorithmic means. And finally, levels of *meta-knowledge*, *i.e.*, knowledge about the extent, reliability, and relative weight of other knowledge, need to be represented as well.

Given that these types of knowledge are encountered, the next question concerns the choice of data structures to be used in the representation. This question, however, exposes two fundamental problems inherent in the negotiation domain: (i) computation is complicated by the superposition of facts, beliefs, stated positions, and underlying interests and preferences, which may all be mutually inconsistent, even within the cognition of a single party; and (ii) even in the calculational mode, the use of the computer is almost always confounded by the non-linear and discontinuous utility functions that are common in complex negotiations [see Clements & Sossen, 1987]. Because of these and other difficulties particular to the domain of negotiation, the choice of data structures and interpretive mechanisms for a negotiation management system is not a trivial task. At this point, it is clear only that the knowledge representation scheme used in such a system must facilitate the synthesis of a negotiated settlement: it needs to be understandable by all parties, and it needs to preserve coherence and internal consistency in a multi-user multi-criterion environment.

2.1 Communication

The need for the system architecture to provide channels for communication is self-evident in the case of remote negotiation. As pointed out in the previous section, the scale and frequency, and hence the cost, of complex negotiations is increasing. Consequently, for geographically dispersed negotiators, the ability to carry out the more routine aspects of a negotiation through teleconferences or other remote communication channels is attractive. Indeed, remote communication may sometimes facilitate the emotional interactions between negotiators: for instance, it may allow tempers to cool down, or encourage admissions and retractions to be made with less embarrassment.

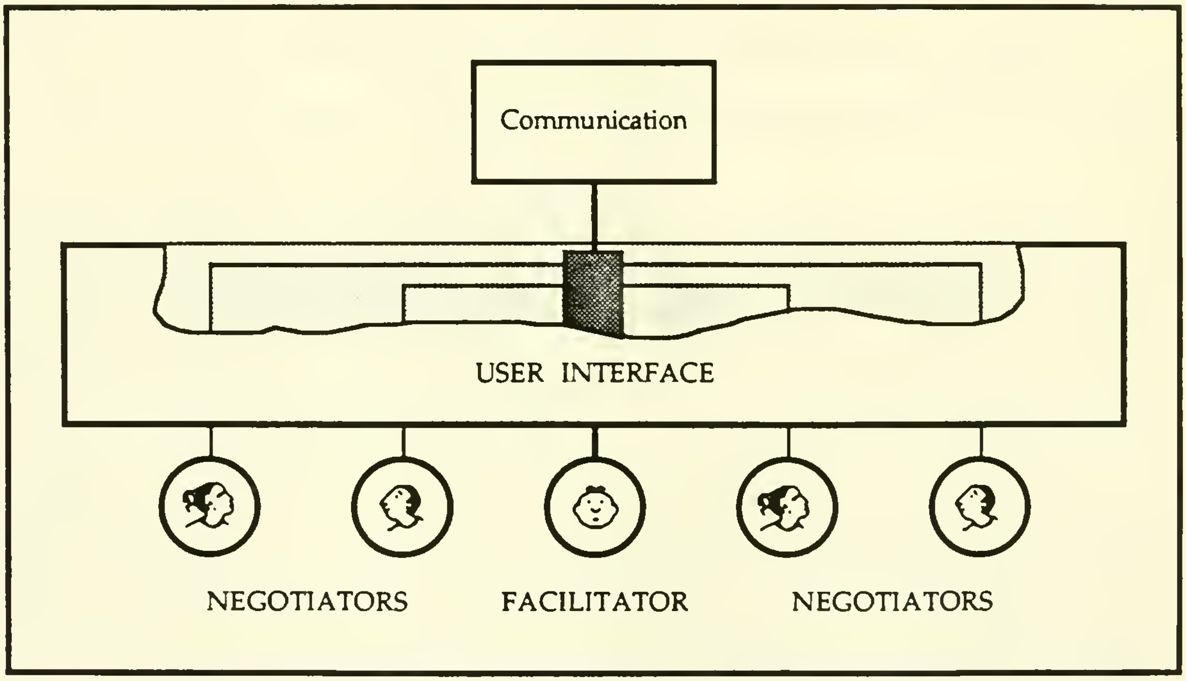

Figure 2: Communication Links Between Parties and Computer

Figure 2 illustrates the general use of the communication facility by negotiators and facilitators. This general use parallels the analysis in Shimanoff's work [1984] on structured communication in small groups: the computer mediates the question of who speaks to whom, when, how often, and for how long, through the use of what media and what decision rule. In addition to these channels for structured interaction, the communication facility also provides access channels into the various tools and models for individual and group experimentation, and for data and model transfer, where appropriate.

In addition, the communication facility serves also as scribe, since it is party to all interactions with the computer system. The related function of model configuration management, however, is currently provided separately by the various modeling tools (see Sections 3 and 4 below). Because of the variety of models and model formats that will be tried as the definition of the system changes, an attempt to centralize this function is premature.

Figure 2 also hints at the special role of the facilitator in negotiation management. Although both negotiator and facilitator use the same interface to the system, the interface distinguishes between them. The need for proper access protocols and for the automatic protection of sensitive data and knowledge has been emphasized by Kettelle [1981]. Consequently, the options available to the facilitator are a super-set of those available to the negotiators. This special status is necessary so that the facilitator can observe and provide assistance in the use of the system. It also implies that the facilitator, or more typically, members of the facilitating team, have more than a superficial knowledge of the workings of the system. It does not imply, however, that the facilitator has access to any private information that any party wishes to store on the system.

Although not addressed in this paper, other methods of facilitating and enhancing communication can provide negotiators with more than simple channels for exchanging views and information. For example, the Colab, an experimental meeting room, provides an environment for the use of several related computer tools for meeting enhancement [Stefik *et al.*, 1987]. Among these tools are Boardnoter, an electronic sketchboard, Cognoter, a system that facilitates electronic brainstorming, ordering of ideas, and evaluation of alternatives, and Argnoter, a computer tool that automates the documentation of proposals, arguments, and evaluations. A different approach – the Planning and Decision Laboratory – is outlined by Nunamaker, Applegate, and Konsynski [1987]. In this metaphor, decision-makers are gathered in a room equipped with workstations and related hardware. Four software tools – Electronic Brainstorming, Stakeholder Identification and Analysis, Issue Analyzer, and Enterprise Analyzer – are used in conjunction with a knowledge base to guide the group in making a decision. Obviously, such approaches hold great promise, especially for groups of negotiators who have overcome the barriers to integrative negotiation. On the other hand, Kay [1987] suggests that there is only limited utility to the use of such group planning techniques:

> "Group Think" ... just doesn't work. ... Most people are so happy when they have an idea that they want to do something about it, the Hollywood syndrome. Most ideas are bad, even by smart and creative people. That is why brainstorming is usually terrible. If you have fifty bad ideas on the board, it is not going to help you to select one of them. It's like cable TV, thirty-five channels of bad stuff.

A different type of communication facility, where the computer takes a more active role in mediating and even arbitrating the dispute, is presented in a parallel paper [Goeltner, 1987].

2.2 Precedent Analysis

In negotiations that are part of a series of very similar cases, such as in mass tort litigation settlements, there is a desire to provide uniform treatment throughout the series. In other negotiations, including labor negotiations, for example, parties and intermediaries might be able to profit from the ideas or mistakes of others in similar circumstances.

The precedent analysis feature is designed to allow negotiators and third parties to explore the history and potential course of a conflict or negotiation and to develop a strategy for resolving it. Prior to its use, a standardized series of questions about a large number of similar conflictual situations is used to elicit information, which is then stored in the precedent database. At the negotiating table, users specify some or all of this information as it pertains to their situation. The system locates within its database those cases that are most similar to the one at hand. This information is presented to the user, together with some analysis. The work of Bloomfield & Beattie [1971], Kettelle [1981] and McGovern [1986], among others, suggests these ideas and provides valuable guidance.

2.3 Risk and Decision Analysis

The degree of certainty with which information is held by various parties is another substantive issue that often arises in a negotiation. In many cases, there is incomplete information about variables that are perceived to be deterministic in nature. In other cases, when the variables themselves are only probabilistically defined, complete knowledge is an impossibility in real terms. In both situations, the eventual outcome of a gain or concession is not immediately obvious, and the management of risk and uncertainty becomes an important function. Therefore, basic tools for decision and risk analysis are included in the system.

By allowing the negotiator to consider the expected rewards and costs associated with each available option, and the multiple probabilities or probability distributions associated with each random variable, these tools enable the calculation of expected values for each possible combination of options and outcomes [see Raker, 1986]. Especially useful for those involved in a negotiation is the subsequent ability to analyze quickly the sensitivity of the optimal set of decisions to changes in assumptions about probability and expected value. Bargaining positions that are favorable under some assumptions may be irrelevant or have a negative effect on the satisfaction of the negotiators and their constituents under other assumptions. Information, interests, or positions that seem crucial at first may be found to be dominated, in the sense that they are made redundant or irrelevant, by other information, interests, or positions. Decision and risk analysis, therefore, can be used in negotiation management to scope the discussion appropriately.

The use of decision and risk analysis may be new to negotiation, but it is obviously not new to decision-making. Raiffa, for example, illustrates with a case study [1982] how the method might be used by an attorney to determine the expected value of settling a case out of court. The premise underlying the inclusion of decision and risk analysis in a computer system designed for negotiation management is that the *joint* use of these methods by negotiators is a valuable extension, and a special case of their use by any single decision-maker. A decision tree that includes explicitly *all* the options available to one party in a negotiation will also include those options that are available to that one party in cooperation with the others.

2.4 Expert Knowledge

An expert system might readily be integrated into a negotiation management system. Possible roles include the following:

i) extend intelligent and context-sensitive guidance in the use of the computer and its facilities, as an on-line hypertext-based help system;

ii) elicit knowledge from participants to help the process along, especially in the difficult area of preference and utility analysis;

iii) offer knowledge and advice as appropriate to individual parties or to the group: sources of expertise for knowledge bases on negotiation might include Alexander's work on message types conducive to conciliation [1979], the concept of principled negotiation as enunciated by Fisher and Ury [1981], and Susskind's rules for effective intercultural negotiation [1987]; in addition, individual parties might use the inference mechanisms of an expert system to understand complicated negotiating instructions, and to test complex proposals for internal consistency; and

iv) provide simple model management capabilities, acting in concert with the communication facility as an interface between the various models and the user [see Dolk & Konsynski, 1984; see also Section 4 below].

These ideas are untested so far, and their feasibility remains to be seen. The design goal is to develop a system that is to some extent customizable by the user for a particular negotiation context, and to aid the user in achieving a better and more organized sense of options and priorities.

2.5 Optimization and Enhancement

Often in a negotiation, parties value the issues differently, so that there are ways in which they could trade and achieve joint gains. Unfortunately, insecurity, exhaustion, or misplaced zeal often subvert these possibilities. A primary element of the integrative bargaining concept, and a primary goal of negotiation management, is the capturing of these joint gains.

In this context, the computer acts as a third party intervenor. It accepts information from the negotiating parties. While keeping the actual information private, the computer reveals to the parties whether or not their stated positions allow any room for negotiation. If so, it offers a communication channel for them to negotiate. If they then reach an agreement, the computer reveals whether or not Pareto-optimal solutions exist that would further benefit both parties. And finally, the computer offers to the parties methods of distributing the further joint gains that are possible – these methods would have been pre-selected, or at least previewed by the parties.

Other authors have addressed Pareto-optimality and the post-settlement enhancement of negotiated outcomes [Kettelle, 1981; Raiffa, 1982; see also Goeltner, 1987]. The application of microcomputer-based multi-criteria decision-making tools in intervention has also been explored. Nagel and Mills [1987], for example, suggests that such tools can be used to change the alternatives being considered by the parties, to change the criteria for evaluating these alternatives, and to change the relationship between alternatives and criteria. However, several difficulties remain. It is not clear how Pareto-optimal solutions can be found when many parties are negotiating coupled or interwoven issues, because the simplifying assumptions of linearity and independence are violated in these cases. Nor is it immediately obvious that such theoretically optimal solutions will be stable if they are indeed arrived at. Being on the Pareto frontier – the goal of the integrative bargainer – is one thing; but choosing one point on that frontier over another – the specialty of the distributive hard-liner – is an altogether different thing.

2.6 Additional Tools and Support Features

In designing an architecture for a computer system for negotiation management, it is important to include modular links for a variety of other assorted tools that are not provided within the system. These tools include such common and generic microcomputer-based 'productivity' items as word and document processors, outliners, spreadsheets, and databases. They also include communication aids, such as graphics editors and the capability to produce explanatory graphics, facsimile service to remote destinations, electronic mail and access to bulletin boards. There are two advantages to the provision and maintenance of modular links to all these tools:

i) the alternative is the provision of these tools as well *within* the system, a duplication of effort that would be frustrating and wasteful;

ii) they are common tools, and most negotiators will be used to them, and will work best with access to them; and

iii) the fact that individual negotiators will be able use their own favorite accessories will enhance their sense of ownership of the process.

3. MODELING THE PROCESS OF NEGOTIATION

A complete model of the process of negotiation must include at least two fundamental elements:

i) a representation of the relevant traits of each party in the negotiation, including as far as possible cognitive variables such as preferences and beliefs, as well as situational variables, such as access to information and control of the negotiation agenda; and

ii) a representation of the interactions among the parties, including, for example, the exertion of influence by one party over another, the formation and disbanding of coalitions, and the substantive nature of proposals and eventual settlements.

These two elements are the heart and soul of SAM, an interactive model that simulates the process of negotiation, using information provided in real time by the parties.

SAM is a hybrid that draws from several modeling sciences, chiefly from game theory and systems analysis. Insofar as game theory deals with the logic of multi-lateral decision-making, SAM is a game-theoretic simulation of the dynamics of a negotiation. On the other hand, insofar as game theory has traditionally dealt with a mathematical search for equilibrium, SAM is an outcast to this tradition.

Game-theoretic models, building upon the two-person games of von Neumann, permit the representation of interacting parties whose decisions take into account the perceived decisions and actions of their opponents [see, for instance, von Neumann & Morgenstern, 1944; Shubik, 1982]. The features common to all game-theoretic models have been summarized by Derakshani [1983]:

i) the number and identity of players are assumed to be fixed and known throughout the analysis;

ii) all players are, and are known to be, fully rational, so that prediction of behavior is possible;

iii) the payoff functions of all players are assumed to be known to themselves and are fixed, or carefully prescribed at any given time;

iv) the analysis is based on a set of assumptions that limit the scope of strategic interactions between players; and

v) communication among the players is restricted in time and content, and highly stylized in form.

Unfortunately, these assumptions abstract away many important real variables. The models do not yield determinate solutions otherwise.

The application of pure game theory to negotiation, therefore, has only a limited usefulness. As many observers have pointed out, there is great difficulty in predicting analytically and narrowly the outcome of a negotiation [see, for example, Lax & Sebenius, 1983]. Myerson [1979] and Axelrod [1984] surmount the difficulty elegantly and extract some interesting conclusions by modeling only very simple or highly abstracted interactions. In the former's theoretical analysis of incentive compatibility and the bargaining problem, for example, it is assumed that there are only a finite number of options available to the negotiators. This assumption is convenient but unrealistic in complex negotiations, where the solution space is more or less *terra incognito*. In general, there are simply too many variables, and too many ways in which they can vary: the aim of prescribing determinate or closed-form solutions is untenable in the analysis of real negotiations.

SAM, therefore, is not meant to be an analytical predictor of stable outcomes. Rather, it is a descriptive mathematical formalization that allows negotiators to check the consistency of basic concepts and images, in order to focus on essentials and break through the barrier of complexity. No monolithic representations of the various parties are sought. Instead, the parties provide the necessary information by interacting with the simulation. Descriptive process models can educate and assist negotiators, and stimulate interaction among them [Wierzbicki, 1983]. SAM takes the idea one step further: it enlists the interactive cooperation of the parties themselves in the creation and use of a descriptive model.

SAM is an acronym for Simulated Agreement Mechanics. The term *agreement mechanics* refers to a set of criteria for collective decision-making that are represented algorithmically in the model. Since there is clearly no single archetypal 'negotiation process' to simulate, SAM offers a group of negotiators a library of algorithms that represent different ground rules for negotiation and group interaction. Additionally, SAM encourages the negotiators to formulate and encode more relevant ground rules of their own conception. The hypothesis underlying the development of SAM is that many of these rules can be coded in algorithms.

One example of a ground rule might be a particular understanding about what constitutes fair treatment within the group. When decision-making authority is shared, as it is among negotiators, the types of agreements that emerge are in large part defined qualitatively by such norms of fairness [Gulliver, 1979]. As an illustration, consider the SAM module designed to investigate the concept of weighted suffrage. In complex negotiations, parties are often classified as either voters or observers, where the observers have no voting rights at all, but are allowed to ask questions and make comments during the negotiations. The norm of fairness operating in this environment might be that *a good negotiated settlement is one that is acceptable to the parties with full voting rights, but which can also be fine-tuned to minimize its unattractiveness to the observers*. Of course, when there are more observers than voters, or when the collective preferences of the observers and voters differ sharply, questions of fairness can and do arise. Using a descriptive SAM model to simulate the process of weighted voting, negotiators might invent voting schemes that are perceived to be more equitable.

Another SAM algorithm embodies the following very common norm: *a good negotiated settlement requires the least total movement by all parties away from their stated settlement ideals*. This simple utilitarian rule is, arguably, at the core of modern Western liberal thinking. It has, however, distinct implications of which a group of negotiators may or may not be aware. Some parties, for example, might accumulate influence by appearing to be more flexible on issues they care less about, and then use the accumulated influence on those issues in which they are more genuinely interested. Other parties might have a dominating influence as soon as they enter the negotiations. Yet others might act as power brokers, by using a superior intelligence-gathering capability. There is also the chance that various coalitions will form among the weaker parties to pool their influence, and that these coalitions might have larger strategic implications for the process. By explicitly addressing these and other possibilities, this SAM module allows the negotiators to question the assumptions on which it is based. (For a discussion of the substantive consequences of norms and ground rules, see Section 4 below.)

Obviously, the situation is more complicated than these simple examples can illustrate. In real negotiations, literally dozens of these norms operate simultaneously, each one pulling or pushing the group toward settlement or chaos. In a sense, SAM's simplistic library of algorithms, which facilitates the search for a rule for aggregating individual preferences, is reminiscent of the notion of 'constitutions' [Arrow, 1951; Sen,1970; Plott,1971]. Shubik [1982] has warned of the difficulty of modeling in this area:

> [T]wo translations of roughly the same verbal description into mathematical language can yield radically different formal conclusions. The verbal description must therefore be refined to bring out the implicit assumptions and hidden distinctionsthat could allow us to separate [them].

But by involving the negotiators themselves in the modeling effort, and by encouraging them to perform in real-time the 'verbal sensitivity analysis' that Shubik describes, SAM escapes his criticisms.

The current goal in this area is to develop a comprehensive library that will include SAM modules for the various norms and decision-making criteria operating in negotiations, from integrative bargaining to the use of private information. The purpose of embodying these criteria and norms in computer algorithms is twofold. First, the analysis gives an insight into subjective concepts such as fairness, and raises questions about patterns of decision-making and the distribution of negotiating power and influence. Secondly, it allows negotiators to gauge explicitly the effect and utility of each of their norms and criteria on the quality of the negotiated settlement. The conditions which might be varied in SAM's process simulation include, among other things, the distribution of influence among the parties, the control of the agenda, and the availability of substantive data as well as confidential tactical information.

Primarily, SAM is meant to be used jointly by the parties to understand the local dynamics of their negotiation, and not to predict its global outcome given some *a priori* evaluation of their utility functions. It could also be used as an evolving research tool to gain insight into the anatomy of the many processes of negotiation, or as a basis for the design of complex interactive games with human participants.

4. MODELING THE SUBSTANCE OF NEGOTIATION

Simulation models that represent the substantive points in controversy have frequently been used in policy-making [for examples, see Holling, 1978; Kraemer, 1985] and, less frequently, in negotiation [see Greenberger, Crenson, & Crissey, 1976; Sebenius, 1984]. But as pointed out earlier, most examples of the use of simulation models in negotiation have been part of an adversarial approach. Typically, each party secures or commissions a detailed model that uses its assumptions and illustrates its point of view favorably. The locus of conflict between the parties is simply transferred to the model domain where, unfortunately, the stakes are increased because of the pseudo-scientific nature of the models and the invocation of rationality and correctness.

What is recommended in this section is different, and might be called 'Meta-Modeling,' to distinguish it from previous uses of simulation modeling in negotiation. While it provides the usual benefits of simulation modeling – chief among which is sensitivity analysis – the Meta-Modeling environment (Figure 3) has three additional features:

i) the synthesis of a broad perspective on the issues through a dynamic linking of separate substantive simulation models that use different modeling methodologies;
ii) the use of a collaborative problem-solving process in the iterative formulation of a single negotiating model; and
iii) the coupling of this single negotiating model with a simulation of the negotiation process.

Essentially, the Meta-Modeling concept is a combination of simple model management provided by a computer and facilitation provided by a third-party facilitator. The reader will note that this use of the term "Meta-Modeling" is different from (but distantly related to) the use of a similar term in artificial intelligence that describes the modeling of whole classes of models [see, for example, Aytaç & Ören, 1986; Mbi, 1987].

4.1 Dynamic Linking of Models

Complex negotiations are usually multi-disciplinary – the use of many different substantive simulation models may be called for, and these models may be of different types. In most cases, sufficiently many models will exist in all categories, and will be known to the parties, so that they may select for use in negotiation the ones that are most relevant to their situation.

Typically, however, each of these models would have been developed in isolation by technical experts in a particular field. Many model types would be involved, each qualitatively different from the others because of the use of different modeling techniques: statistical regression modeling; systems dynamics; linear programming and optimization; probabilistic game theory; queueing theory; the list goes on, each technique ideally suited for some substantive contexts and inappropriate for others. Not only would the various models require training and knowledge to understand and manipulate, but they would also not necessarily be compatible with each other because of the use of the different modeling techniques and different levels of description.

In order to compensate for these difficulties, the Meta-Modeling environment provides a Meta-Model Manager to coordinate the dynamic linking of separate substantive models in two different modes. 'Zooming,' the functionality provided by the first mode of linkage, refers to vertical movement through the hierarchy of model complexity. In any given area of expertise, a hierarchy of simulation models usually exists in the form of an inverted tree, with highly aggregated models at the top, and very finely detailed basic models at the bottom. The tree structure is propagated because each model contains many variables and sub-routines, each of which could itself be the subject of a model, at a level of greater detail. The ability to zoom up and down along this hierarchy is important because it allows modelers and model-users to specify their requirements or queries in convenient levels of detail.

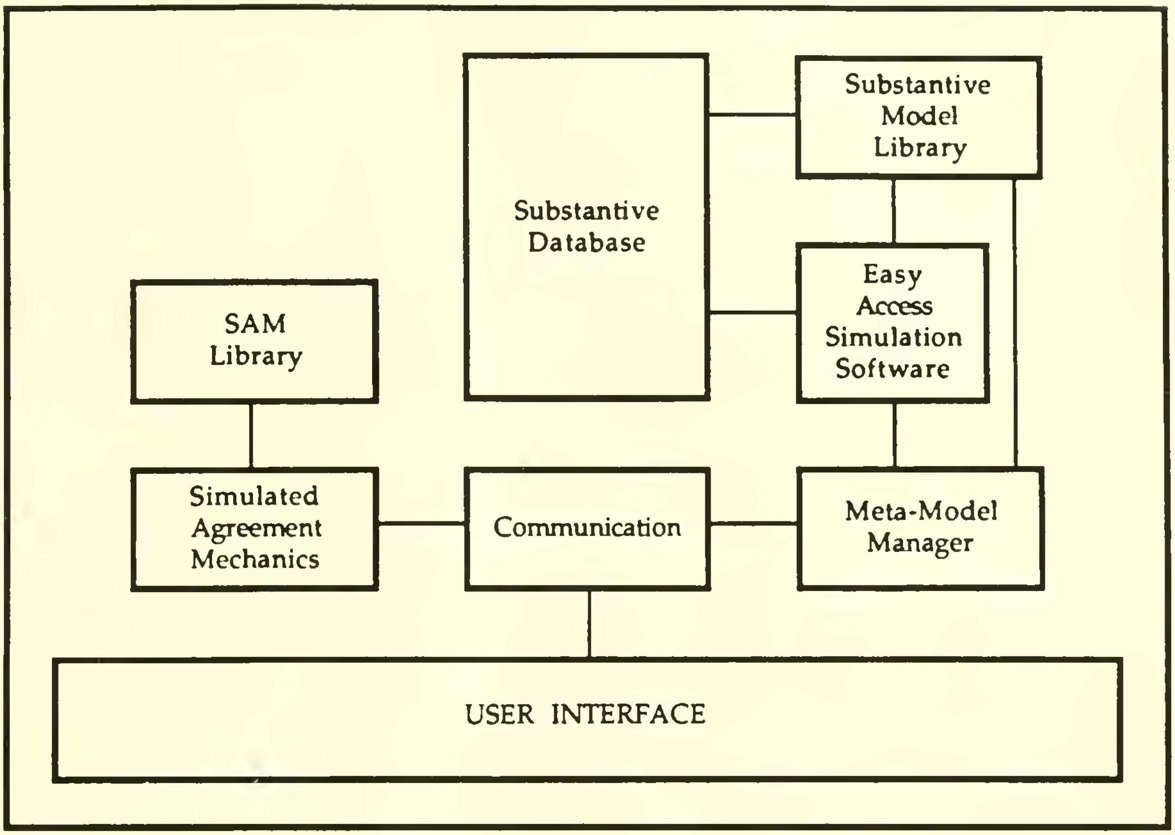
Substantive Database
Substantive Model Library
Easy Access Simulation Software
SAM Library
Simulated Agreement Mechanics
Communication
Meta-Model Manager
USER INTERFACE

Figure 3: Simulation of Process & Substance

In the Meta-Modeling environment, the ability to zoom is useful because it simplifies negotiator access to both models and information. Since negotiators in any given negotiation are bound to be less interested in modeling than in negotiating, it is imperative that they have easy access to any modeling involved. One way to ensure this easy access is through the provision of simple and user-friendly modeling software (see below). With guidance, the negotiators can use this software to jointly construct simple but useful models with very little trepidation. When linked to more rigorous models, these simple models provide a easily accessible front-end to the model tree. And because the model manager can provide an annotated outline of the entire tree or any sub-tree, negotiators seeking access to certain level of detail can locate themselves conveniently.

The ability to zoom has other implications as well. In their analysis of the uses of models in dispute resolution, Nyhart and Dauer [1986] present a scheme in which they identify three process tools, each a variation on the uses of models in conflict management: (i) ordained models, where the models used in the process are not primarily developed by the parties; (ii) model-building, where the parties build the models themselves; and (iii) non-model alternate dispute resolution, where the use of models is not at the focus of the process. By making it possible for negotiators to build simple models as a front-end to technically better models, the Meta-Modeling environment provides a fourth alternative in this scheme. For instance, negotiators might be able to save time and effort by using pre-built and pre-tested models, and yet achieve a sense of ownership over the process by writing their own front-end model scripts.

The second mode of dynamic linking provided in the Meta-Modeling environment might be called 'bridging.' It refers to horizontal movement between parallel hierarchies of models in different substantive contexts. The ability to bridge effectively between different substantive models, whether or not they are built by the negotiators themselves, is useful because it would allow facilitators, negotiators, and their expert advisors to relate issues and interests to each other, thus compensating each for their narrow specializations.

In the Meta-Modeling environment, models that are dynamically linked through zooming and bridging are in some sense 'aware' of the models that surround them. For example, before beginning a series of simulation experiments, negotiators can specify certain global phenomena or effects they are looking for or seeking to avoid in the simulation. While they then make changes in a particular local model or sub-model, they are kept aware of (i) the global prerequisites for and (ii) the global consequences of their various changes. In this way, it is hoped that negotiators will be able to achieve a better understanding of the substantive system (or systems) over which they are negotiating.

Some words of caution: it is possible to make too much of these ideas, since they are tied so closely to semantic definitions and artificial categories. In many cases, the substantive issues in a negotiation are not sufficiently understood by anyone, and cannot simultaneously be modeled simply and accurately. In other cases, separate models might exist that each describe individual issues or groups of issues, but that cannot be used together to form a comprehensive and meaningful picture, because of contradictory assumptions or vastly different motivations.

4.2 A Single Negotiating Model

The idea of a 'single negotiating model' is derived by analogy and extension from the concept of a 'single negotiating text,' a relatively new technique for structuring the process of negotiation.

Used in the negotiations at the Camp David Summit and over the United Nations Convention on the Law of the Sea, the single negotiating text is a device for concentrating the attention of the parties on the same composite text [see Raiffa, 1982]. As Raiffa notes, complex multi-party negotiations are usually too diffuse to be effective unless focused on a single document. By negotiating an entire agreement holistically, the parties are sure at all times that their perception of the progress of the negotiations is up to date on even the finest details. Furthermore, the formulation of comprehensive proposals and counter-proposals that cover the whole ground of settlement is conducive to the discovery of joint gains, at least more so than would be a reductionistic splitting of different hairs at every turn.

If one views the use of substantive models in negotiation as an adjunct to the process, then the idea of a single negotiating model can be derived by extension. As a negotiation proceeds, the requisite set of models is developed, and the latest version of this set of models that has gained the acceptance of all parties and is used as the basis for all proposals, can be included in the single negotiating text.

On the other hand, if one views the use of models as the new locus of negotiation, then the single negotiation model can be derived by analogy. When substantive models are used in negotiation, they themselves often become the subject of controversy and negotiation. While the idealist may insist that substantive models should strive for correctness and accuracy, and that 'fact' should not be negotiated, the truth is that many (if not most) models of complex systems are not primarily shaped by fact, but by basic assumptions. These assumptions are usually made by modelers according to their individual preferences, biases, and attitudes towards risk, all of which are subjective, and even subconscious. When negotiators create or use models, they are subscribing to these assumptions. And, significantly, the bases for the assumptions – namely the negotiators' preferences, biases, and attitudes towards risk – often change in the course of the negotiations, according to the negotiators' perceptions of themselves and others [for examples of this dynamic, see Sebenius, 1981]. The interaction between negotiators presents an opportunity for the examination of these assumptions. The idea of a single negotiating model serves the useful purpose of fomenting explicit discussion on the subject [Nyhart & Samarasan, 1987]:

> As a *single negotiating model* is built, the computer allows the playing of "what if", so that the parties can see which issues are particularly sensitive to (or powerful for) change in the context under study. The collaborative development of this single negotiating model allows the parties to focus on the issues and inter-relationships rather than on their positions; in addition, it exposes unrealistic private assumptions; and finally, it can foster a good working relationship amongst the negotiators.

The full potential of the single negotiating model concept will not be realized, however, if negotiators rely on second-hand accounts of models and model results. As explained earlier, the willingness of negotiators to use a given model or result depends on the availability of easy access. User-friendly modeling software is provided in the Meta-Modeling environment so that negotiators can build simple and highly abstracted models containing only the essential features, and zoom downwards from there as necessary (see Figure 3; the reader should note that all elements shown explicitly in the figure are meant to be used jointly by the parties; in addition to these components, parties may also maintain their own confidential tools, models, and data).

A graphical implementation of systems dynamics is used as the construction kit for the single negotiating model built and maintained by the negotiators (with or without the guidance of modeling facilitators). In this implementation, the negotiators are presented with a set of components common to all dynamic systems. The essential features of many systems can be clearly and effectively modeled with this set of components in such a way that parties can identify with the various attributes of the model. The potential to experiment with creative solutions by asking what-if questions, by performing comprehensive sensitivity analyses, and by conjuring up scenarios and pursuing them through systematic simulation experiments enhances considerably the level of understanding with which negotiators approach contextual questions.

Systems dynamics was chosen as the primary modeling methodology for three reasons:

i) it is a powerful methodology that relies for its greatest impact on user intuition and the search for deep and global understanding;

ii) it highlights the inter-relatedness of the issues, in the form of positive and negative feedback loops and other causal relationships;

iii) it can be explained in a dynamic and graphical form easily comprehended by non-experts (see, for example, STELLA™, commercially available from High Performance Systems, Inc.).

Nevertheless, the methodology has its detractors. Greenberger, Crenson, and Crissey, for example, argue [1976] that its disregard for actual data results in a lack of empirical rigor that is both "unscientific and irresponsible." In order to correct for these, and perhaps other deficiencies, different and complementary methodologies such as regression analysis and stochastic techniques will be made available in future versions of the system as soon as they can be made easily accessible to the non-experts who, ideally, would participate in the creation and iteration of the single negotiating model.

4.3 Coupling Feasibility and Agreeability

The third and final feature of the Meta-Modeling environment that distinguishes it from previous applications of substantive simulation models in negotiation is the dynamic relationship between substantive and process simulation that is at the heart of the system (see Figure 3). The rationale for combining an interactive SAM simulation of process and a descriptive simulation of substance is obvious: settlements arrived at through negotiation should be, ideally, both technically feasible and politically agreeable. The idea that a 'yesable' proposition is sufficient is dangerous, at least in the complex negotiations that are the concern of this paper. By combining a SAM process model that includes norms and decision criteria with a parallel Meta-Model simulation of the substantive side of the negotiation, the system allows negotiating parties to investigate the process implications of their statements of negotiating position, and the substantive consequences of those statements, as well.

5. USING MODELS IN NEGOTIATION MANAGEMENT

There are numerous ways in which negotiators and facilitators can use existing computer tools and techniques to help them in their negotiations. To start with, the fifteen functions that are listed in Figure 4 appear to be useful in a wide range of contexts (as discussed earlier) and may prove to be helpful to third party neutrals, facilitators, mediators, and technical experts, as well as to negotiating parties themselves. The argument for the use of these capabilities is made elsewhere [see Nyhart & Samarasan, 1987]. In the rest of this section, the discussion will focus on the need for a process of negotiation that incorporates these capabilities in a natural way.

A review of the available means of dispute resolution in the law and in common business practice reveals that the potential of the computer is not being fully exploited. Although some inroads are being made in innovative jurisdictions [see, for example, McGovern, 1986], neither the traditional processes of dispute resolution – from adjudication to mediation – or the non-traditional processes – from 'med-arb' to the 'mini-trial' – explicitly engage the computer.

Moreover, it appears that, for several reasons, the computer, especially in the form of the joint use of computer models, is not easily or usefully introduced into these dispute resolution processes. In the first place, the majority of the processes assume a more or less adversarial relationship among the parties, whereas computer modeling requires cooperation and the sharing of substantive information.

Secondly, most practising third-party intervenors are computer-naive, and tend to play down the usefulness of models and modeling [Clements & Sossen, 1987]. Clearly, no tool will ever be used in a situation where it appears to threaten the established roles of those who might use it.

Negotiators and facilitators can use models and modeling to help them:

1) Establish a consensual database as a foundation for agreement;
2) Assess the impact of uncertainty and change in the database;
3) Set a common research agenda to collect useful additional data;
4) Probe inequalities of power, influence, and access to data;
5) Track the formation of coalitions and clusters;
6) Formulate new procedures for making collective decisions;
7) Practice cross-cultural negotiating styles and tactics;
8) Provide communication links for bargaining and discussion;
9) Communicate effectively while protecting secret information;
10) Discover the areas of potential agreement among sub-groups;
11) Suggest settlements that minimize the need for compromise;
12) Evaluate the substantive impact of proposed settlements;
13) Enhance initial agreements through Pareto-optimization;
14) Monitor the implementation of the final agreement; and
15) Reach an amicable solution should disputes arise anew.

Figure 4: The Uses of Models and Modeling in Negotiation Management

Furthermore, the path and success of a negotiation is very sensitive to timing. Since the use of a computer ties the user to a certain pattern of timing, computer-assisted negotiation is not simply a matter of embedding the computer in existing processes. It is not clear how negotiators might address or take advantage of the asynchrony introduced by the use of a computer. It has been speculated, for example, that the timing forced by the use of a computer model was critical in the most impressive and well-known example of the use of computer models in dispute resolution – the negotiations surrounding the United Nations Convention on the Law of the Sea [see Sebenius, 1984; Antrim, 1985].

And finally, one should note that the fifteen-activity list in Figure 4 represents a widening of what is normally considered the role of negotiation. No existing process of negotiation attempts to address the entire span of fifteen functions. In fact, very few practising negotiators, mediators, or arbitrators even recognize some of these functions to be part of their responsibility.

Designed to take these considerations into account, negotiation management is a process for dispute resolution through which the full potential of the computer can be harnessed. In resonance with the new emphasis on integrative bargaining, this process might be called 'integrative negotiation.' It is based on a *collaborative model-building* effort by the negotiators, through which they agree on the validity of the data, and then on the dynamics of the issues, and finally on the consequences of their agreements. Such a joint model-building effort could precede actual bargaining, or it could run in parallel, the two concurrent processes informing each other [for an example from the Law of the Sea negotiations, see Sebenius, 1981]. Because information is the essential ingredient in a negotiator's recognition of interests, preferences, and positions, there is a natural link between integrative negotiation, which requires access to a great deal of information, and the modeling sciences, which can provide access to information in the first place.

Working directly on the computer, either by themselves or with the help of a neutral facilitation team, a group of negotiators would seek consensus on substance and process. Substantive issues would include agreement on the sources of data and models to be used, the choice of parameters to represent the issues under negotiation, and on the values and relative importance to be assigned to those parameters. In this respect, the guidance offered by expert in systems analysis will be invaluable [see, for example, Majone & Quade, 1980]. And procedural issues would include protocols for the sharing of information, for the validation of particular models and substantive conclusions derived from them, and for the design of group decision-making procedures that effectively utilize the information made available by the models. Not all the models forwarded for use in the joint modeling effort will be worthy of the consideration of the group, and criteria will be needed for the acceptance of models. Two sources of ideas in this area will be the work of Nyhart and Dauer [1986] on the use of scientific models in dispute resolution, and of Raiffa [1982] on the questions posed for organizing the taxonomy of disputes. Both have consequences for the appropriate and effective use of models in negotiations.

To avoid any misunderstanding, it is worth stating that this paper does not recommend the use of computer tools and methods to the exclusion of all others. As presented in Section 1 of this paper, the claim is that these tools and methods are a useful supplement to other established techniques of dispute resolution in complex negotiations. The introduction of models and modeling into anything but a voluntary and perhaps even non-binding process would be problematic. On the other hand, many negotiators, after gaining a certain familiarity with the tools outlined in this paper, and the philosophy behind the extending of these tools, may indeed be willing to consider their serious and systematic use. While the idea of cooperating with a negotiating 'opponent' over a piece of 'foreign' technology is difficult to accept at first, it becomes more acceptable to negotiators and facilitators to the extent that it combines a qualitative feel for the processes of negotiation with a quantitative approach towards the modeling of contextual issues.

6. SOME CONCLUDING REMARKS

In the seventeenth-century, two thinkers dominated the debate on the use of models and modeling, although they used different words for these concepts. One school of thought, identified with Leibniz, held that ideas are a sufficient basis for modeling. The human mind, it was argued, contains innate, discoverable knowledge, and this knowledge can be used adaptively to make predictions. Most mathematical and scientific models built today are still rational and deductive in this way. The Lockean school of thought, on the other hand, placed all its faith in data gathered empirically. Generally, the empirical inductivists held that truth resides in the data, or must be derived inductively therefrom. Eventually, of course, Kant settled the debate to the satisfaction of most philosophers, holding that theory and data are inseparable, a conclusion that seems self-evident to today's sophisticated set.

But the use of models is still not problem-free. Greenberger, Crenson, and Crissey, for example, make the perhaps ominous observation [1976] that:

> ... [a] formal model of a given reference system is another system expressed in a formal language and synthesized from representations of selected elements from the

> reference system and their assumed inter-relationships. ... [Formal models] invite examination and revision, but in so doing, they provoke debate and disagreement. ...

Clearly, the use of models in negotiation management can surface problems as well as solve them. Only disappointment is in store if one expects the use of models, or of any technology, for that matter, to be a panacea. Technology is easily abused, and the old computer aphorism of "garbage in, garbage out" applies just as strongly in this area. But in a complex negotiation, when there are few alternatives, the use of models can help explicate matters even without claiming to provide 'right' answers.

At this point, computer modeling for negotiation management does not require prodigious amounts of original research in such exotic fields as artificial intelligence and the mathematics of non-linear systems analysis. But although the uses of models discussed in this paper are, for the most part, not located in the giddy heights of computer science, they are relatively new to the world of negotiation. And instead of focusing on absolute correctness or mathematical elegance, negotiation management begins with the goal of providing negotiators a set of useful tools to help them perform a variety of functions. The emphasis is more on the synthesis and use of these computer tools by the parties than it is on the theoretical analysis of negotiation.

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